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Specification and Drawings as originally filed, with Application for Patent Serial No: **2,379,732,** on April 2, 2002, by **TURBOCOR INC.,** assignee of Huai Lin, for "System and Method for Controlling an Electric Motor".

PRIORITY DOCUMENT

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ABSTRACT

A system and method are provided for controlling a three-phased motor terminal voltages in relation to both changes in speed and torque of the motor, whereby phase currents are first rotated from a stationary frame to two decoupled current components in a rotor synchronous frame, which enable to derive a voltage along a quadrature axis and a voltage along a direct axis thereof, before rotating back the quadrature and direct axis voltages from the rotor synchronous frame to the stationary frame to yield the motor terminal voltages.

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TITLE OF THE INVENTION

System and method for controlling an electric motor

FIELD OF THE INVENTION

[0001] The present invention relates to the control of an electric motor. More precisely, the present invention is related to a system and a method for controlling an electric motor.

BACKGROUND OF THE INVENTION

[0002] Generally, in order to control an electric motor such as a permanent magnet motor, information is needed about the phase, the frequency and the amplitude of the electric motive force ("emf") voltage generated by the rotation of the motor rotor, in order to determine a voltage to be applied to the motor terminals.

[0003] One possible method to obtain this information is to use a position sensor, which results in increased costs and reduces the reliability of the method since it is subject to changes in the ambient condition such as noise and temperature and impurity contamination for example.

[0004] Another possible method is to estimate the emf, by utilizing the characteristics of the motor. However, such a method requires high computation speed for high-speed motor, which leads to high cost. Moreover, since the characteristics of the motor are dependent on the ambient conditions, the complexity of the control method can be rather high.

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[0005] From the foregoing, it appears that although a number of methods are known to control permanent magnet motors, current methods either require complicated computation or are to be adapted according to the design of permanent magnet motor.

[0006] Therefore, there is a need for a system and a method, which allow controlling an electric motor in a simple, versatile and reliable way.

OBJECTS OF THE INVENTION

[0007] An object of the present invention is therefore to provide an improved motor controller system and method.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] In the appended drawings:

[0009] Figure 1 is simplified diagram of a motor controller system according to an embodiment of the present invention; and

[0010] Figure 2 is a flowchart of a method using a motor controller system according to an embodiment of the present invention.

DESCRIPTION OF THE EMBODIMENT

[0011] The system 10 shown in Figure 1 comprises a permanent magnet motor, referred to hereinafter as PM motor 12; a power stage 14; and a motor controller in the form of a park vector rotator unit 16.

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[0012] The PM motor 12 is a three-phase electric motor provided with a rotor and a stator (not shown), each one of the phases carrying a current, respectively i_a, i_b and i_c. These phases currents are sensed and used by the park vector rotator unit 16 to generate three voltage-controlling signals V_a, V_b and V_c, which are then supplied to the power stage 14.

[0013] For example, a power stage provided by Semikron, in particular the SKiiPACK™ 342 GD 120-314 CTV has been successfully used as the power stage 14 comprised in the system according to an embodiment of the present invention.

[0014] The angular speed "ω" of the motor is controlled by a user by setting a value representing the speed of the PM motor 12 into the system 10. The user chooses a reference current value "I*", normally set at 0, but other values may be selected.

[0015] In a nutshell, the park vector rotator unit 16 generates two continuously rotating angles having instantaneous values θ_{n+1} and $-\theta_n$, wherein the negative sign represents an opposite direction of rotation, the subscript "n+1" labels a current computing angle, and the subscript "n" labels the previous computing angle.

[0016] The main steps of the method according to the invention will first be listed, in reference to Figure 2.

[0017] In a first step 100, the three currents i_a, i_b and i_c, from the three phases of the PM motor 12 are determined by the use of standard current sensors. Then, in a following step (200), they are processed in a inverse park

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vector rotator 18, which rotates them by an angle $-\theta_n$, to output the two currents I_d and I_q.

[0018] In step 300, these two currents I_d and I_q are used to compute a current torque "T" of the PM motor 12, which is used to compute the current rotating angle θ_{n+1} (step 400).

[0019] Additionally, the two currents I_d and I_q are used to compute two voltage outputs V_q and V_d (steps 500 and 600). These are finally rotated in a park vector rotator 20 by the rotating angle θ_{n+1} to yield three voltage controlling signals V_a, V_b and V_c (step 700).

[0020] Coming back to Figure 1, the steps of the method of the present invention will now be described with more details.

[0021] The current computing angle is derived in response to changes of the speed ω and of the torque T of the PM motor 12 from the following equation:

$$\theta_{n+1} = \theta_n + k_1 \times \omega + k_2 \times T \quad (1)$$

where k_1 and k_2 are constants.

[0022] As seen in Figure 1, the phase currents i_a, i_b and i_c are directed through lines 12a, 12b and 12c to a first inverse park vector rotator 18, which rotates them by the angle $-\theta_n$, to output the two currents I_d and I_q, according to the following relations on the d-q axis fixed on the rotor axis:

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$$I_d = 2/3 \times [i_a \times \cos(\theta_n) + i_b \times \cos(\theta_n + 120°) + i_c \times \cos(\theta_n - 120°)] \quad (3)$$

$$I_q = 2/3 \times [i_a \times \sin(\theta_n) + i_b \times \sin(\theta_n + 120°) + i_c \times \sin(\theta_n - 120°)] \quad (4)$$

[0023] It is to be noted that either the three currents i_a, i_b and i_c from the three phases of the PM motor 12 are measured, or only two of them, the third phase current being calculated from the other two phases since, as is known in the art: $\sum_{three\ phases} i = 0$.

[0024] The I_d and I_q rotated values are further used to generate a first voltage output V_q which takes into account an error between the preset value I^* and I_d, according to the following equation on the d-q axis fixed on the rotor axis:

$$V_q = PI\,(I^* - I_d) + k_3 \times I_q \quad (5)$$

where k_3 is a constant, "PI" refers to a proportional and integral operator, defined as follows:

$$PI(x) = ax + b\int x\, dt$$

where a and b are constants and the integration is over time.

[0025] The I_d and I_q rotated values are also used to generate the second voltage output V_d, according to the following equation on the d-q axis fixed on the rotor axis:

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$$V_d = k_5 \times I_d + k_4 \times I_q \times \omega \quad (6)$$

where k_4 and k_5 are constants.

[0026] Moreover, the speed ω is set by the user as stated hereinabove, whereas the torque T can be calculated by the following formula:

$$T = (V_d \times I_d + V_q \times I_q) / \omega \quad (2)$$

using the I_d and I_q currents and V_d and V_q on the d-q axis fixed on the rotor frame, as determined hereinabove.

[0027] The two voltages V_d and V_q in the continuously rotating reference frame are then submitted to a second park vector rotator 20, whereby they are rotated by the angle θ_{n+1}, to produce three voltage controlling signals, namely V_a , V_b and V_c, which control the power unit 14, according to the following equations:

$$V_a = V_d \times \cos(\theta_{n+1}) + V_q \times \sin(\theta_{n+1}) \quad (7)$$

$$V_b = V_d \times \cos(\theta_{n+1}+120°) + V_q \times \sin(\theta_{n+1}+120°) \quad (8)$$

$$V_c = V_d \times \cos(\theta_{n+1}-120°) + V_q \times \sin(\theta_{n+1}-120°) \quad (9)$$

[0028] It is to be noted that the values k_1 to k_5 are constants that the user sets, when designing the system 10, based on a number of parameters, including the sampling rate of the computer to be used, condition of the power

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drive, sensitivity of the current sensors, the characteristics of the motor and etc..

[0029] From the foregoing, it should be apparent that the present invention provides for a system and a method whereby the motor terminal voltages are self-adapting. More specifically, three currents signals are first rotated from a stationary frame to two decoupled current components in a rotor synchronous frame, along a direct axis (I_d) and a quadrature axis (I_q) respectively. Then, on the first hand, a voltage (V_q) along the quadrature axis is derived therefrom, by applying a proportional and integral operator on the direct axis current component added with a product of a constant and the current components along the quadrature axis (see relation 5). On the other hand, a voltage (V_d) along the direct axis is derived, as a product of the direct axis current component added to a product of the speed of the motor by the quadrature current component (see relation 6). Finally, the quadrature and direct axis voltages (V_q and V_d) thus computed are rotated back from the rotor synchronous frame to the stationary frame to yield the motor terminal voltages (V_a, V_b and $V_{c,}$ see relations 7-9).

[0030] Interestingly, the present system and methods allows for a continuously updating value of the angle in response not only to changes of speed but also to variations in the torque of a motor.

[0031] Although the present invention has been described hereinabove by way of preferred embodiments thereof, it can be modified, without departing from the spirit and nature of the subject invention as defined in the appended claims.

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What is claimed is:

1. A motor controller system generally as shown and/or described herein.

2. A method for controlling a motor as shown and/or described herein.

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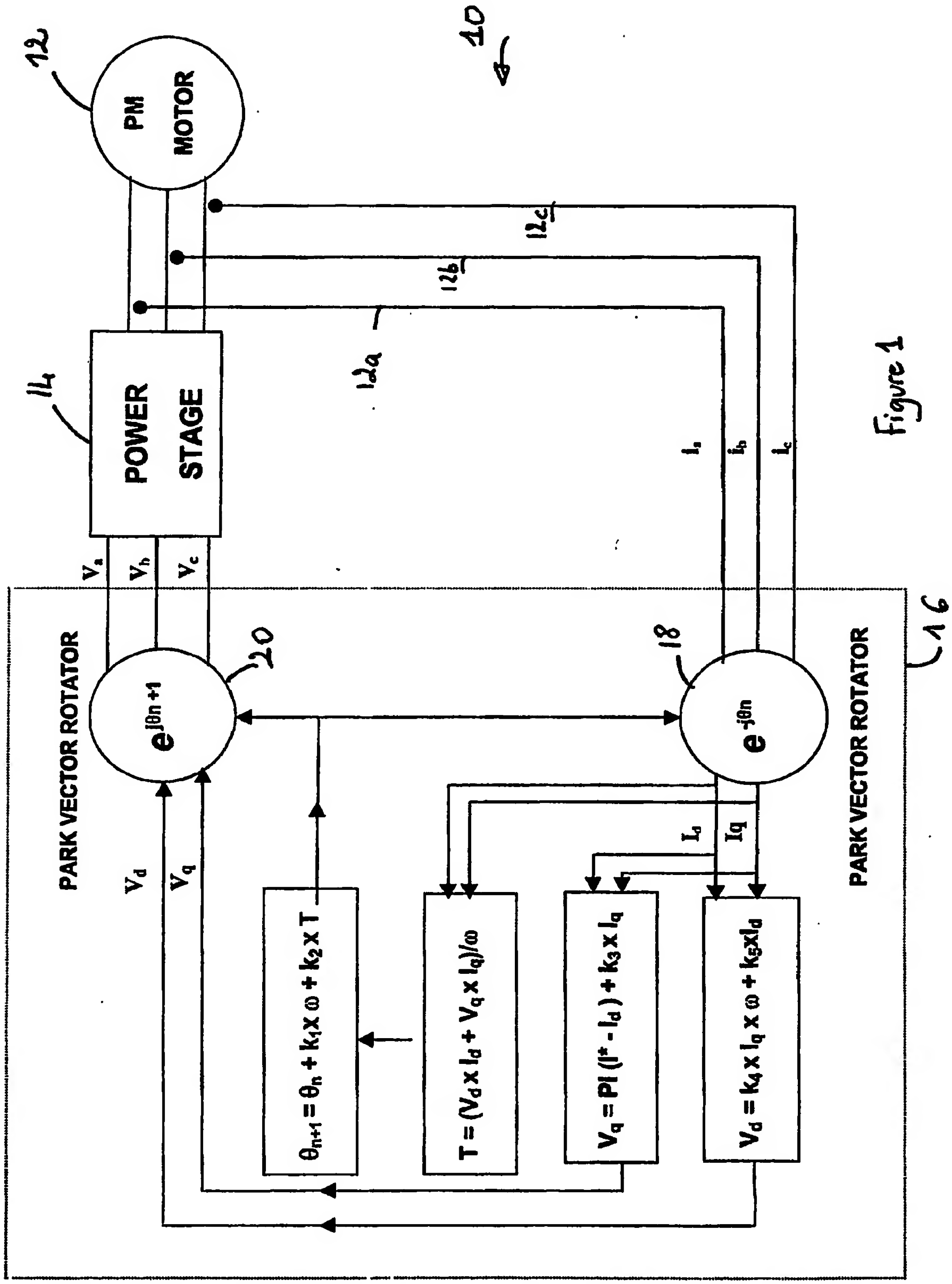

Figure 1

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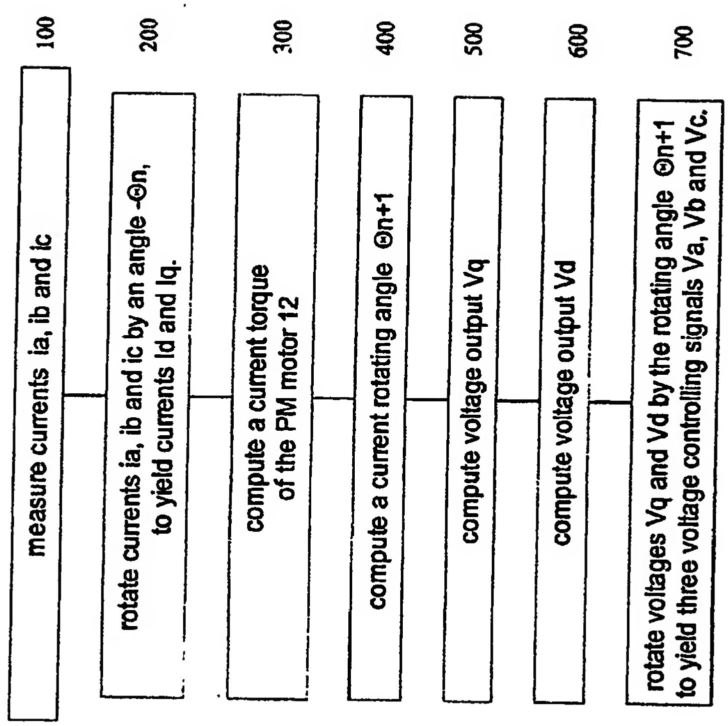
Figure 2



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